DOI: 10.14355/ijer.2014.0301.01

Comparitive Study of Biogas Production: Utilization of Organic Waste

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Abstract

Biogas technology provides an alternative source of energy mainly from organic wastes. Using local resources, viz. cattle waste, kitchen waste and other organic wastes, energy and manure are derived. It is produced when bacteria degrade organic matter in the absence of air. In this paper, an attempt has been made to design and test the performance of plastic made portable floating type biogas plant of volume capacity 0.018 m^3 for outdoor climatic condition of IIT Delhi, New Delhi, India. In this work, cow dung and kitchen waste were compared for biogas production of 30 kg slurry capacity in batch system.

During these periods, the temperature, solar radiation and relative humidity have been measured; in addition, the constituent of biogas, pH, volume and rate of biogas production were analysed at different level of temperature observation on daily basis. Physical and chemical analysis of biogas and slurry have also been carried out along with the comparison of other fuel sources which can be saved by the use of biogas plant.

Keywords

Slurry; Biogas; Batch system; Floating Type Biogas Plant

Introduction

In order to minimise the risk to the environment and human health, economically feasible solutions are sought for the treatment of solid waste particularly in urban areas. A plan to turn solid organic waste (kitchen waste) into energy through different technology has been possible; however, maximum energy recovery, and less discharge are possible through anaerobic digestion that seems viable economic option for the country like India. Biogas is produced from organic wastes by concerned action of various group of anaerobic bacteria through anaerobic decomposition. Globally, the reduction of green house gas emissions particularly of CO_2 has become more important. Currently much of the carbon dioxide emitted to the atmosphere the result of anthropogenic activities from the use of the fossil fuel in the transportation and energy sectors. Significant emission reductions may be achieved in the energy sector by improving efficiency through the use of alternative fuels. Through the use of biogas plant, the CO_2 emission can be reduced in the atmosphere.

It has been suggested that the rate of biogas production and the period to achieve the optimum temperature are function of the temperature of the slurry. Also, for a required production rate of biogas, the period to achieve the optimum temperature should be reduced (Tiwari GN et al 1988; Tiwari GN et al 1986). The performance of a greenhouse integrated biogas plant was analysed with the fundamental aim to reduce thermal loss to ambient in harsh cold climates (Usmani JA et al 1996). Due to the lower temperature, biogas production decreases drastically and may stop. Thus, to enhance biogas production, a higher digester temperature than ambient temperature is required. The green house concept should be integrated for larger capacity biogas plant (Lau AK et al 1987). Solar greenhouse assisted biogas plant in hilly region recommended and it has come to conclusion that biogas- green house hybrid system may be successful in hilly regions where average temperature remains below 37°C throughout the year (Vinoth KK et al 2008). It can also evaluate the carbon credits earned by energy security in India and also analyses the return on capital for biogas plants with and without embodied energy (Prabhakant et al 2009). A heat exchanger connected to a flat plate collector has suggested for heating of the slurry (Tiwari GN et al 1992). Installation of PVC greenhouse type structure over a biogas plant allow solar heating of the substrate from 18°C to about 37°C (Gupta RA et al 1988; Sodha MS et al 1987; Sodha MS et al 1989 and Tiwari GN et al 1997).

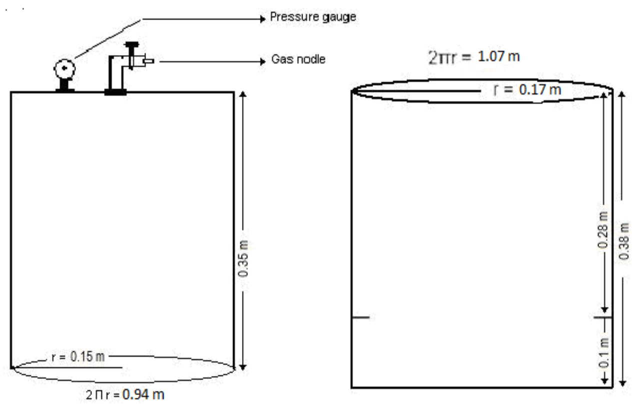
A kind of efficient and renewable energy has been taken into consideration after cleaning sulphur through physical, chemical and biological methods such as absorption and bioreactor, which can be used to cook, heat, light and generate power and thus

reducing the dependency on fossil fuels and curtail green house gas (GHG) emissions (Lastella G et al 2002). The slurry and residues from the biogas process can be used as an organic fertilizer to replace the use of chemical fertilizer on the farm (Hu GQ 2008; Zhou CX et al 2004; Liu Y et al 2008 and Chen RJ 2007). Anaerobic digestion process produces a higher biogas yield when running on a mixture of animal manure and vegetable/crop waste rather than animal manure alone, and biogas production is considered the most suitable bioenergy technology in China (Wu CZ et al 2009). Biogas can be produced from nearly all kind of biological feedstock types, within these from the primary agricultural sectors and from various organic waste streams from the overall society. The largest resource is represented by animal manure and slurries from cattle and pig production units as well as from poultry, fish etc. In India, million tones of animal manure are produced every year. When untreated or poorly managed, animal manure becomes a major source of air and water pollution. Nutrient leaching, mainly nitrogen and phosphorus, ammonia evaporation and pathogen contamination are some of the major threats. The animal production sector is responsible for 18% of the overall green house gas emissions, measured in CO_2. Furthermore, 65% of anthropogenic nitrous oxide and 64% of anthropogenic ammonia emission originates from the world wide animal production sector (Steinfeld H et al 2006). If handled properly, manure can be valuable resource for renewable energy production and a source of nutrients for agriculture. There is a positive relationship between N surplus and GHG emission. Per kg of N surplus corresponds with a GHG emission of approximately 30-70 kg CO_2-equivalents (Oenema O et al 2006).

In this paper an attempt has been made to study the rate of biogas production in plastic made portable biogas plant. Through this paper we have tried to evaluate the rate of biogas production by the use of kitchen waste and cow dung; moreover, the rate of biogas production was compared with the other energy sources used for cooking purposes like LPG, Kerosene and Coal (Table 2).

Experimental Setup and Instrumentation

Here we used biogas plant (have 30 kg slurry capacity) above the ground so the digester and dome both can directly receive the solar radiation. The diameter and height of both digesters have been taken as 0.34 m and 0.38 m respectively. Similarly, the same diameter, depth and weight of both the domes have been taken as 0.30 m, 0.35 m and 0.18 kg, respectively (Fig. 1 and 2).



(a) Dome (b) Digester

FIG. 1 CROSS SECTIONAL VIEW OF DOME AND DIGESTER

FIG. 2 PHOTOGRAPH OF PLASTIC MADE BIOGAS PLANT

Calibrated thermocouples have been used to measure slurry temperature inside the biogas plant by using digital temperature indicator of resolution 0.1°C. This field study has been done at IIT Delhi, New Delhi, under the different climatic condition of 2010 - 2011.

These observations have been taken during day time due to presence of sunlight at 9:00 am, 1:00 pm and 5:00 pm every day. Ambient temperature, slurry temperature, relative humidity, and solar intensity have been measured during this experiment. Gas productions have been recorded on daily basis by the observation of upliftment height of dome. This upliftment height is multiplied by $2\pi r$ and the volume of biogas production is measured every day. Here we used toddler bags to carry biogas sample which has tested through gas chromatography.

Methodology and Experimental Observation

Different parameters like solar intensity, ambient temperature, slurry temperature and average humidity are measured on daily basis. These data have been

taken at the interval of 4:00 hours between 9:00 am to 5:00 pm due to presence of solar radiation. Three readings have been taken in every day at 9:00 am, 1:00 pm and 5:00 pm. Here we have compared the biogas production from cow dung and kitchen waste in plastic made biogas chamber. Under the analysis, we have calculated the average of solar intensity and relative humidity at these three different times in a day until the biogas production inside the biogas chamber stop. In this manner, we have also calculated the average ambient temperature and average slurry temperature to find the different result and observation. The production rate and methane fraction have also been observed under the influence of various temperature ranges during the experimental work in New Delhi, India.

Result and Discussion

In these observations, all the research analysis has been done under batch system. In the batch system, the slurry has been added once to the digester for whole duration of the process. It has been observed that the production of biogas depends on temperature and the solar intensity.

This analysis has been done under 12 week observation for cow dung and kitchen waste, July 1, 2010 to September 28, 2010. This season was under monsoonal effect. In the case of cow dung, biogas production and methane fraction started from the second (15th days) and third week (20th days), of the slurry feeding inside the biogas chamber. The rates of biogas production increased from the 2nd week to 4th week and then continuously started to decrease due to substrate availability and bacterial activity in cow dung. In the case of kitchen waste synthesis of gas has been started from the second day of the slurry feeding inside the biogas chamber but methane fraction was obtained on third day. Solid waste of kitchen waste rapidly disintegrated by microorganism so the production of biogas stopped after 15th day. The retention period of biogas production are maximum 15 days in the case of kitchen waste and for cow dung it is 90 days in batch system.

Kitchen waste has less solid content (organic material) as compared to cow dung so it is rapidly decomposed by the anaerobic microbes. We have collected this 5 kg kitchen waste from staff canteen in IIT Delhi, Hauz khas, New Delhi, India. This kitchen waste is mainly carbon and nitrogen content organic waste like rice, pulses, kidney beans, potato and bread. There has no role of humidity and precipitation under biogas production. Initially solar intensity increases upto two weeks but after this it decreases due to cloudy weather condition. The slurry temperature is always more than ambient temperature during the whole experimentation period in both biogas plants.

TABLE 1 COMPARISON BETWEEN COW DUNG AND KITCHEN WASTE

Characters	Cow dung	Kitchen waste
Capacity of biogas production	0.018 m^3	0.018 m^3
Slurry capacity	30 kg (15 kg cow dung + 15 lt water)	30 kg (8 kg kitchen waste + 16 lt water + 6 kg inoculums)
pH	7.2	7.3
Biogas production in days (start and stop)	15 and 70	2 and 15
Methane fraction (%)	20 and 58	3 and 10
Maximum methane fraction (%)	47	52
Total biogas production (m^3)	0.410 (90 days)	0.258 (15 days)

TABLE 2 THE AMOUNT OF OTHER FUEL SOURCES WHICH CAN BE SAVED BY THE USE OF 8 kg (1:2 ratio) KITCHEN WASTE IN RESPECT OF ICAR DATA

No.	1 m^3 biogas (approximately 6 kWh/ m^3) is equivalent to :	0.258 m^3 biogas production will be equivalent to :
1	Diesel, Kerosene (approx. 12kWh/kg) 0.5 kg	Diesel, Kerosene (approx. 12kWh/kg) 0.12 kg
2	Wood (approx. 4.5 kWh/kg) 1.3 kg	Wood (approx. 4.5 kWh/kg) 0.33 kg
3	Cow dung (approx. 5 kWh/kg dry matter) 1.2 kg	Cow dung (approx. 5 kWh/kg dry matter) 0.31 kg
4	Plant residues (approx. 4.5 kWh/kg dry matter) 1.3 kg	Plant residues (approx. 4.5 kWh/kg dry matter) 0.33 kg
5	Coal (approx. 8.5 kWh/kg) 0.7 kg	Coal (approx. 8.5 kWh/kg) 0.18 kg
6	City gas (approx. 5.3 kWh/ m^3) 0.24 m^3	City gas (approx. 5.3 kWh/ m^3) 0.06 m^3

Source: According to ICAR paper (report issued by Indian Council of Agricultural Research, New Delhi),

This analysis has been done under 15 days for kitchen waste. In this observation we have taken a specific ratio of kitchen waste and water with fixed amount of inoculums. Inoculums are the anaerobically digested slurry containing anaerobic bacteria which are responsible for biogas production. These kitchen waste and water are in the ratio of 1:2 with fixed amount of inoculums. In the batch feeding result of kitchen waste and cow dung, kitchen waste had good result on the basis of production of biogas and methane fraction. In respect of solid waste, kitchen waste has lesser mass

than cow dung so the rate of decomposition of kitchen waste is fast during experiment.

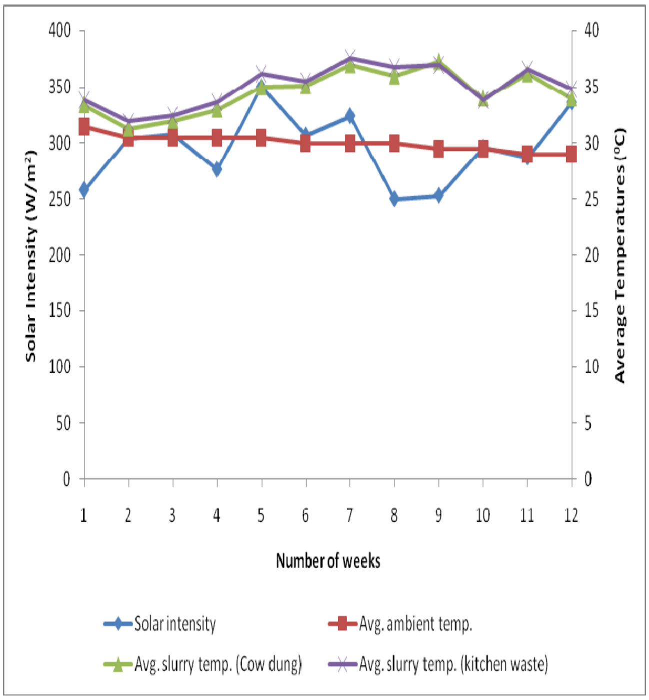


FIG. 3 THE WEEKLY VARIATION OF SOLAR INTENSITY, AVERAGE AMBIENT TEMPERATURE AND AVERAGE SLURRY TEMPERATURE OF COW DUNG AND KITCHEN WASTE

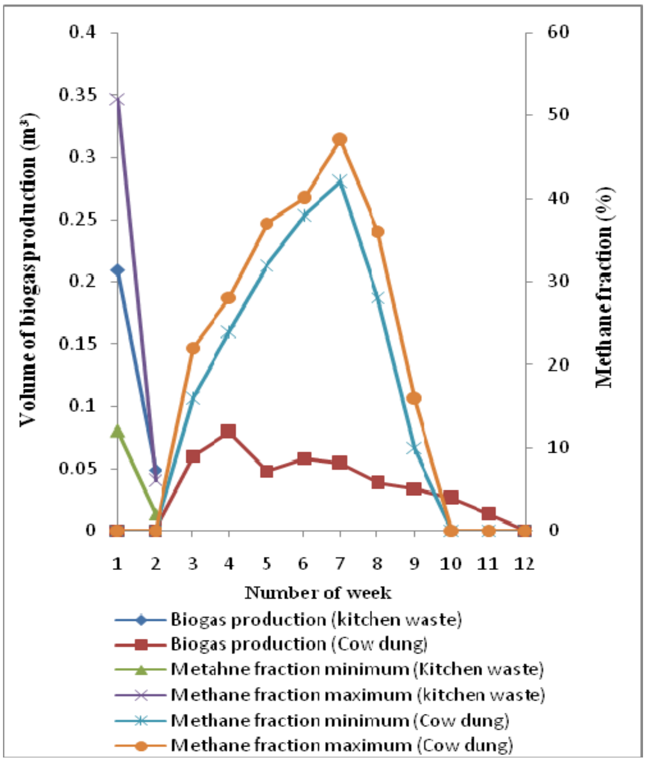


FIG. 4 RATE OF BIOGAS PRODUCTION AND METHANE FRACTION OF COW DUNG AND KITCHEN WASTE SHOWN ON WEEKLY BASIS

In this observation we got better result from kitchen waste in respect of biogas production and methane fraction compared to cow dung in this biogas plant. In the case of biogas production, cow dung and kitchen waste produce 0.410 m³ (90 days) and 0.258 m³ (15 days) respectively. Methane fraction is also more inside the kitchen waste (Table 1). During experimentation, average solar intensity, average ambient temperature, minimum and maximum range of methane fraction and the rate of biogas production have been observed in every day, as shown in weekly average basis (Fig. 3 and 4).

Conclusion and Recommendation

In all these measurement, compared with the cow dung, kitchen waste is better in terms of biogas production and methane fraction. Solid content of kitchen waste is lesser than cow dung so the activity of microorganism is very fast. Utilization of kitchen waste in an apartment, hostel, hotel etc. is more useful in community level work where a lot of other energy sources can be saved utilized for cooking purposes like LPG, kerosene, coal etc. In my campus of IIT Delhi, India, there are 13 hostels where approximately 5000 students are living. Every day a lot of kitchen waste generates considerable source of organic waste in biogas production. In the author's another paper the economical prospect of LPG compared with biogas production from kitchen waste in my campus will be discussed.

In that way, kitchen waste will be the best alternative under a community level biogas production. Here our research was just under a proto type biogas plant but if we will made this at a big level, it will generate more biogas production and increase their utilization under multiple role.

ACKNOWLEDGMENT

We are thankful to the Centre for Rural Development and Technology (CRDT), IIT Delhi, and UGC (University Grants Commission), Bahadur Shah Zafar Marg, New Delhi for biogas testing and financial assistance respectively.

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